

One fundamental requirement shared by humans with all higher terrestrial life forms, including insect wings, higher land plants and other vertebrates, is a complex, fractally branching vascular system. NASA's VESSEL GENERATION Analysis (VESGEN) software maps and quantifies vascular trees, networks, and tree-network composites according to weighted physiological rules such as vessel connectivity, tapering and bifurcational branching. According to fluid dynamics, successful vascular transport requires a complex distributed system of highly regulated laminar flow. Microvascular branching rules within vertebrates, dicot leaves and the other organisms therefore display many similarities. One unifying perspective is that vascular patterning offers a useful readout that necessarily integrates complex molecular signaling pathways. VESGEN has elucidated changes in vascular pattern resulting from inflammatory, stress response, developmental and other signaling within numerous tissues and major model organisms studied for Space Biology.

For a new VESGEN systems approach, we analyzed differential gene expression in leaves of *Arabidopsis thaliana* reported by GeneLab (GLDS-7) for spaceflight. Vascular-related changes in leaf gene expression were identified that can potentially be phenocopied by mutants in ground-based experiments. To link transcriptional, protein and other molecular change with phenotype, alterations in the Euclidean and dynamic dimensions (x, y, t) of vascular patterns for *Arabidopsis* leaves and other model species are being co-localized with signaling patterns of single molecular expression analyzed as information dimensions (i, j, k, \dots). Previously, *Drosophila* microarray data returned from space suggested significant changes in genes related to wing venation development that include EGF, Notch, Hedgehog, Wingless and Dpp signaling. Phenotypes of increasingly abnormal ectopic wing venation in the (non-spaceflight) *Drosophila* wing generated by overexpression of a Notch antagonist were analyzed by VESGEN. Other VESGEN research applications include the mouse retina, GI and coronary vessels, avian placental analogs and translational studies in the astronaut retina related to health challenges for long-duration missions.